INENTEC®

Today's waste, tomorrow's clean energy℠

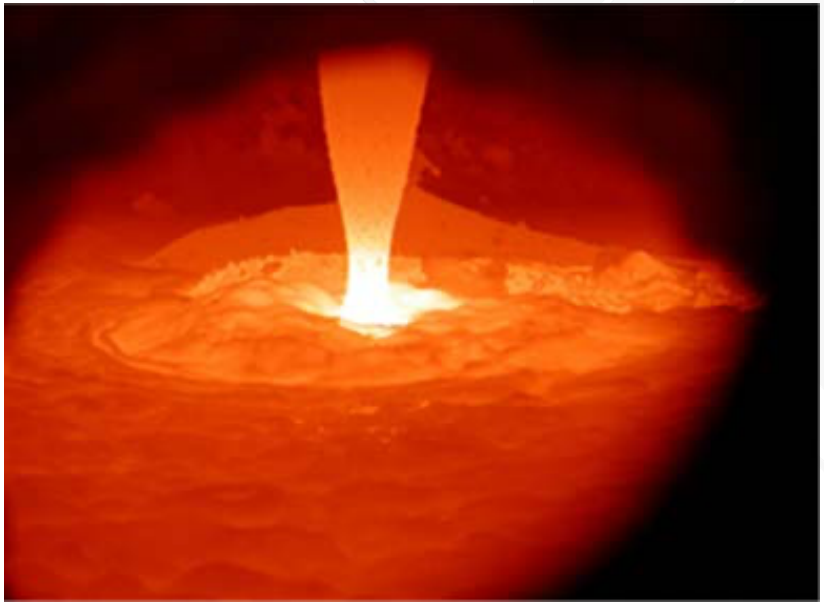
Plasma Gasification Technology for Efficient Conversion of Waste into Chemical and Energy Products

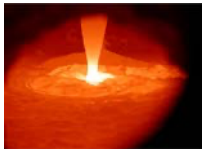
November 2020

www.inentec.com

OUTLINE

- Introduction to InEnTec Inc.
- Technology Overview
- Example InEnTec Facilities
- Summary





Introduction to InEnTec

OVERVIEW

- Founded in 1995, based in Washington State, USA
- InEnTec owns proprietary ***plasma gasification technology*** that converts waste into renewable chemicals and energy
- Technology based $300 million R&D funding (US Department of Energy), developed in collaboration with MIT and Battelle National Laboratory
- Technology has very low environmental impact

Massachusetts Institute of Technology

Battelle
The Business of Innovation

55+ PATENTS AROUND THE WORLD

(12) **United States Patent**
Cohn et al.

(10) **Patent No.: US 10,273,414 B2**
(45) **Date of Patent: *Apr. 30, 2019**

(54) **RENEWABLE ELECTRICITY CONVERSION OF LIQUID FUELS FROM HYDROCARBON FEEDSTOCKS**

(71) Applicant: **INENTEC INC**, Richland, WA (US)

(72) Inventors: **Daniel R. Cohn**, Cambridge, MA (US); **Jeffrey E. Surma**, Richland, WA (US); **Leslie Bromberg**, Sharon, MA (US)

(73) Assignee: **InEnTec, Inc.**, Bend, OR (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 254 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/267,021**

(22) Filed: **Sep. 15, 2016**

(65) **Prior Publication Data**

US 2017/0002271 A1 Jan. 5, 2017

Related U.S. Application Data

(63) Continuation of application No. 14/077,094, filed on Nov. 11, 2013, now Pat. No. 9,469,533, which is a (Continued)

(51) **Int. Cl.**
C10G 2/00 (2006.01)
C01B 3/24 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***C10G 2/32*** (2013.01); ***C01B 3/24*** (2013.01); ***C01B 3/36*** (2013.01); ***C01B 13/0229*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC C01B 3/24
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,341,069 A 7/1982 Bell et al.
5,713,195 A 2/1998 Bronicki et al.
(Continued)

FOREIGN PATENT DOCUMENTS

WO 2004071947 8/2004

OTHER PUBLICATIONS

Bartholomy, , "Renewable Hydrogen From Wind in California", Proceedings, National Hydrogen Association, 20 pages (Mar. 2005).
(Continued)

Primary Examiner — Nina Bhat
(74) *Attorney, Agent, or Firm* — Dorsey & Whitney LLP

(57) **ABSTRACT**

A method for converting renewable energy source electricity and a hydrocarbon feedstock into a liquid fuel by providing a source of renewable electrical energy in communication with a synthesis gas generation unit and an air separation unit. Oxygen from the air separation unit and a hydrocarbon feedstock is provided to the synthesis gas generation unit, thereby causing partial oxidation reactions in the synthesis gas generation unit in a process that converts the hydrocarbon feedstock into synthesis gas. The synthesis gas is then converted into a liquid fuel.

20 Claims, 8 Drawing Sheets

(12) **United States Patent**
Bromberg et al.

(10) **Patent No.: US 10,316,262 B2**
(45) **Date of Patent: Jun. 11, 2019**

(54) **REGENERATOR FOR SYNGAS CLEANUP AND ENERGY RECOVERY IN GASIFIER SYSTEMS**

(56) **References Cited**

U.S. PATENT DOCUMENTS

(12) **United States Patent**
Cohn et al.

(10) **Patent No.: US 10,273,414 B2**
(45) **Date of Patent: *Apr. 30, 2019**

(54) **RENEWABLE ELECTRICITY CONVERSION OF LIQUID FUELS FROM HYDROCARBON FEEDSTOCKS**

(58) **Field of Classification Search**
CPC C01B 3/24
(Continued)

(12) **United States Patent**
Surma et al.

(10) **Patent No.: US 9,994,474 B2**
(45) **Date of Patent: *Jun. 12, 2018**

(54) **COMBINED GASIFICATION AND VITRIFICATION SYSTEM**

2300/16 (2013.01); *C10J 2300/1634* (2013.01); *C10J 2300/1846* (2013.01); *Y02P 40/58* (2015.11)

(12) **United States Patent**
Surma et al.

(10) **Patent No.: US 9,914,890 B2**
(45) **Date of Patent: *Mar. 13, 2018**

(54) **GASIFICATION SYSTEM**

(56) **References Cited**

(12) **United States Patent**
Batdorf et al.

(10) **Patent No.: US 9,771,532 B2**
(45) **Date of Patent: Sep. 26, 2017**

(54) **PRESSURIZED PLASMA ENHANCED REACTOR AND METHODS FOR CONVERTING ORGANIC MATTER TO GAS PRODUCTS**

2200/12; C10J 2300/1238; C10J 2300/1884; C10J 3/66; C10J 2200/156; C10J 2300/0906; C10J 2300/0946; C10J 2300/0959; C10J 2300/0976; C10J

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AWARDS

#1 Waste-to-Value Project in the World

- Biofuels Digest

Technology Innovation Award – Energy

- The Wall Street Journal

One of the "25 Companies to Watch in Energy Tech"

- BusinessWeek

Top Innovator

- Seattle Business Magazine

One of "20 Ways to Build a Cleaner, Healthier, Smarter World"

- Scientific American

"Award of Excellence in Sustainable Technology"

- Platts Global Energy Awards

The Carbon Rescuers: 20 Top Waste projects and breakthroughs that capture used carbon from the waste pile for new uses

June 4, 2018 | Jim Lane

Tweet Share Mail Share

#1 Commercial time: Aemetis embarks on $158 million cellulosic ethanol project in California

So, it's big news this week that Aemetis completed its operation of an integrated demonstration unit for more than 120 days of continuous operations with 94% uptime, meeting the requirements for a federal USDA 9003 Biorefinery Assistance Program guaranteed loan.

In partnership with its key technology providers InEnTec and LanzaTech, Aemetis successfully optimized the integration of an advanced arc furnace and gas fermentation technologies to convert waste biomass into low carbon, renewable cellulosic ethanol and fish meal. The unit was built at the InEnTec Technology Center in Richland, Washington and demonstrated the fully integrated system, including biomass handling, gasification, gas clean up, waste treatment and distillation systems.

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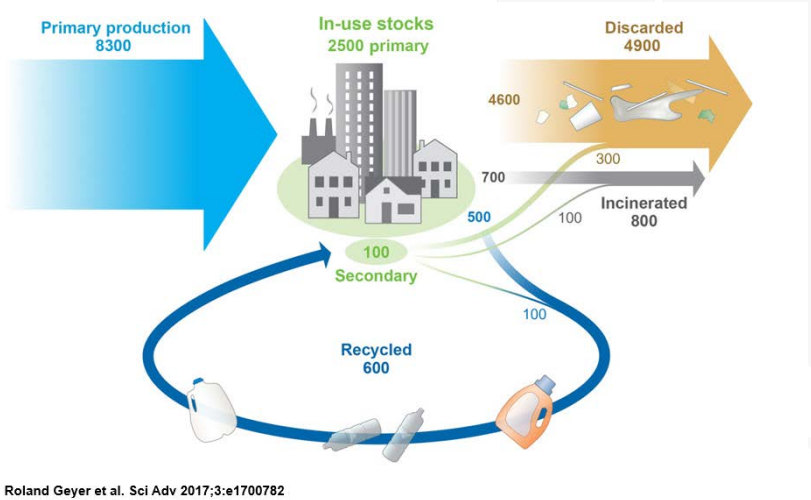
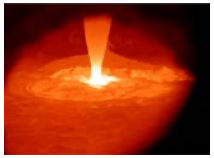
INENTEC'S BUSINESS FOCUS

- Waste Plastic and Plastics Circularity
- Distributed Hydrogen
- High Value Waste (Medical, Hazardous, Chemical and Industrial)
- Municipal Solid Waste to Energy Products
- Biomass to fuels



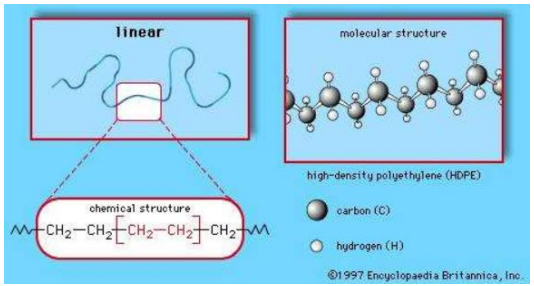
Roland Geyer et al. Sci Adv 2017;3:e1700782



Technology Overview

WHAT IS GASIFICATION?

- Elemental recycling: Gasification cracks feedstocks into their atoms and reforms those atoms into simple molecules.
- Example: Post-Consumer High Density Polyethylene (HDPE)

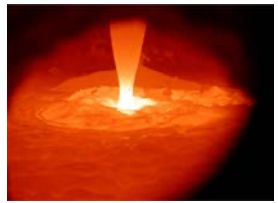


ALS

Date Received: July 1, 2020

Certificate of Analysis

Sample Date & Time:		Lab #:	Carbon D5291 Moist. Free wt%	Hydrogen D5291 Moist. Free wt%	Nitrogen D5291 Moist. Free wt%	Oxygen Calculated Moist. Free wt%	Sulfur D4239 Moist. Free wt%	Heating Value E711 As Received BTU/lb	Heating Value E711 Moist. Free BTU/lb
6/26/20	0825	T2001063-001	85.56	14.5	<0.1	<0.01	<0.03	19,637	19,639
6/26/20	0830	T2001063-002	85.86	14.4	<0.1	<0.01	<0.03	20,047	20,047
6/26/20	0835	T2001063-003	85.16	14.2	<0.1	<0.01	<0.03	19,762	19,762



Gasification with optimized mix of steam and oxygen:

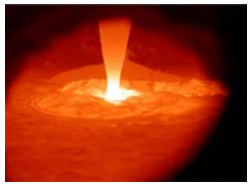
$C_xH_yO_z + H_2O \longrightarrow xCO + yH_2$

Synthesis Gas: Simple Molecules

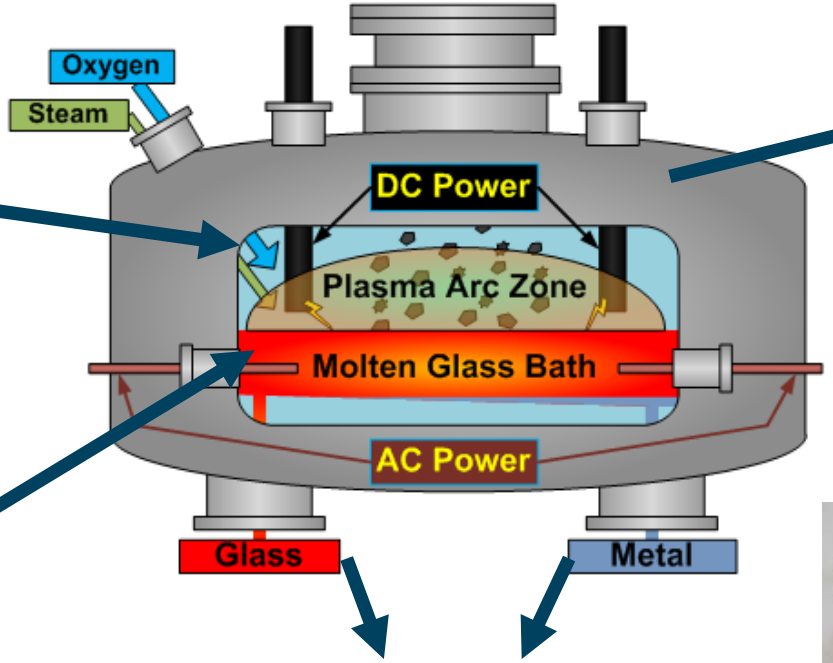
H_2, CO, CO_2, H_2O

PROPRIETARY PEM® TECHNOLOGY

High Temperature Plasma Arc (8,000 to 10,000 C)



Alternating Current Joule - Glass Bath (1,000 to 1,500 C)



Primary Product:
Synthesis Gas (Syngas)
H_2, CO, CO_2

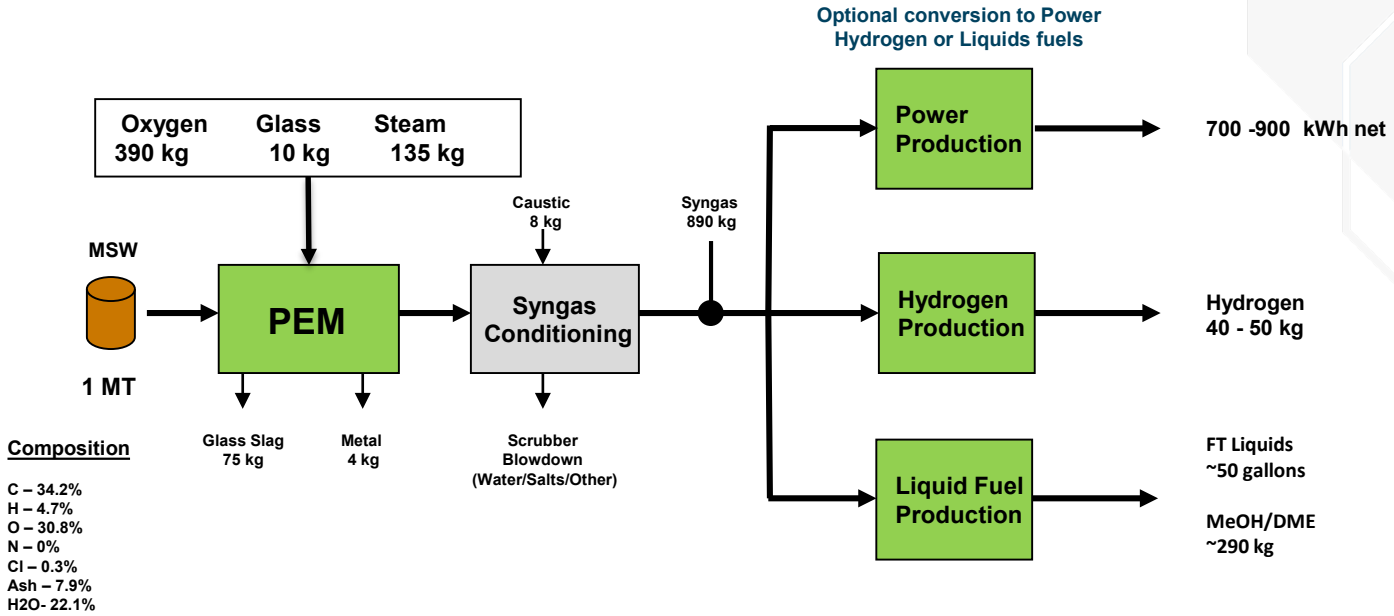
What would be ash in a combustion system is converted into glass and metal.

GLASS

- Non leachable, not a hazardous waste
- Large volume reduction (95+%) from original feedstock stream
- Can be used to make products

ITEM	METAL (including compounds)	USEPA TCLP Test Limit (ppm)	UNI 10802_2002 Test Limit (mg/l)	Analyzed Leachate (mg/l)
1	pH			9.83
2	Tot. Dis. Solids		400	100
3	D. Org. Carbon		50	< 1
4	Phenol Index	Not Applicable	0.1	< 0.01
5	Arsenic (As)	5.0	0.05	< 0.001
6	Barium (Ba)	100.0	2	0.05
7	Boron (B)	Not Applicable	Not Applicable	
8	Cadmium (Cd)	1.0	0.004	< 0.001
9	Chromium (Cr)	5.0	0.05	0.001
10	Copper (Cu)	Not Applicable	0.2	0.003
11	Lead (Pb)	5.0	0.05	0.002
12	Mercury (Hg)	0.2	0.001	< 0.001
13	Molybdenum (Mo)	Not Applicable	0.05	< 0.001
14	Nickel (Ni)	Not Applicable	0.04	0.001
15	Antimony (Sb)	Not Applicable	0.006	< 0.001
16	Selenium (Se)	1.0	0.01	< 0.001
17	Silver (Ag)	5.0	Not Applicable	
18	Thallium (Tl)	Not Applicable	Not Applicable	
19	Zinc (Zn)	Not Applicable	0.4	0.01
20	Chlorides (Cl)	Not Applicable	80	3.4
21	Fluorides (F)	Not Applicable	1	< 0.1
22	Sulphates (SO4)	Not Applicable	100	< 1
Sample results reported with "<" represent results below the detection limit specified.				

EXAMPLE MASS BALANCE - PER TON FEED



ULTRA-CLEAN SYNGAS HAS MANY USES . . .

Wide Range of Feedstocks:

- Municipal solid waste
- Post-consumer plastic
- Medical waste
- Hazardous waste
- Biomass
- Construction and Demolition
- Auto shredder residue
- Tires
- Commercial and Industrial Waste
- Liquids and Solids

Ultra-Clean Syngas:

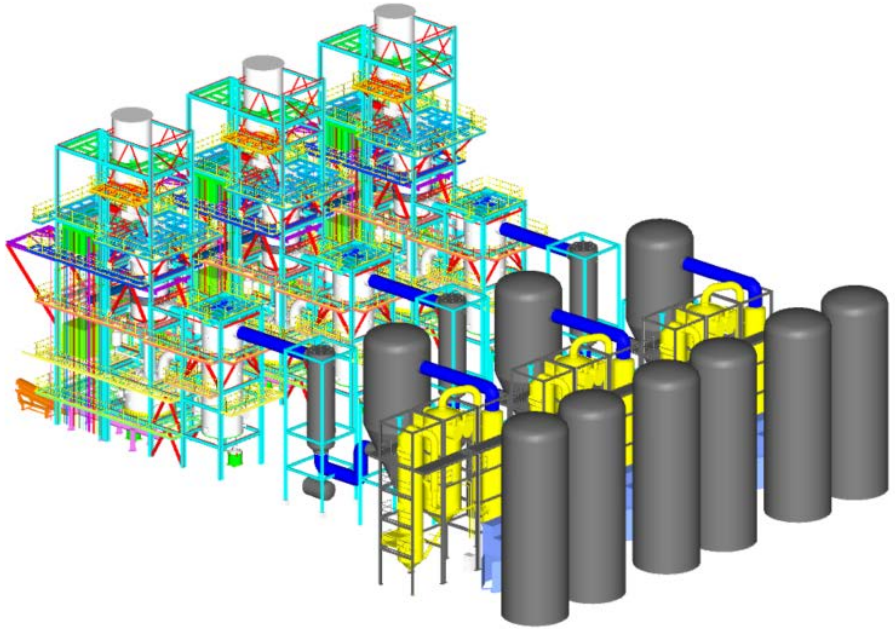
A basic building block of chemical and plastics production

Wide Range of Products:

- "Chemical-grade" syngas for input to chemical and plastic production
- Ethanol
- Methanol
- Hydrogen
- Electricity
- Others

MODULAR, SKID-MOUNTED SYSTEM

125 - 150 TPD
PEM Module



REUSE EXISTING CARBON

Ref: The World Bank

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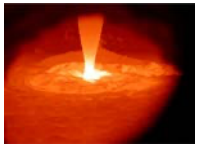


Example Facilities

OREGON HYDROGEN PRODUCTION

- Feedstock: Industrial and Medical Waste
- Product: Hydrogen
- Status: Restarted in August October 2020; commercial operation expected in 1Q 2021

KAWASAKI HEAVY INDUSTRIES, JAPAN

- PCB Destruction
- 5 ton/day demonstration system

GLOBAL PLASMA, TAIWAN

- Processed medical waste and batteries

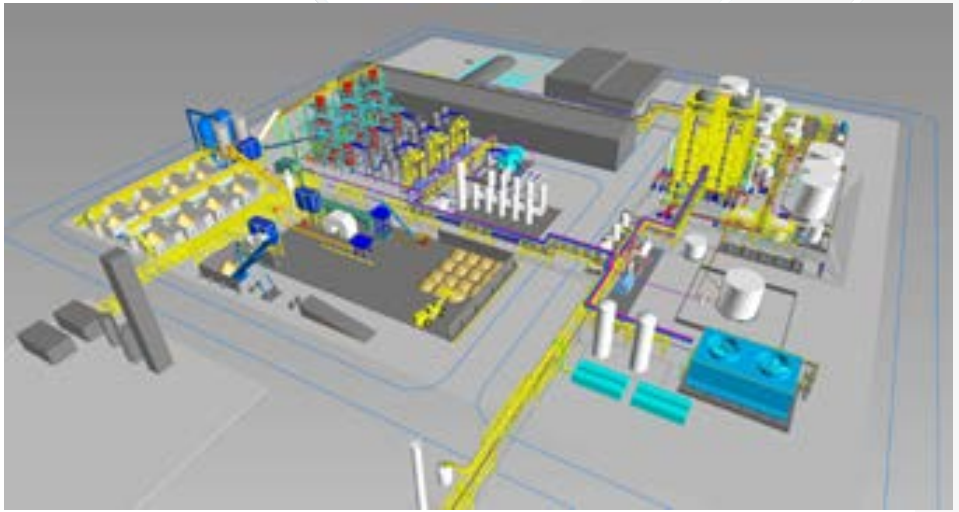
DOW CORNING CORPORATION, MICHIGAN

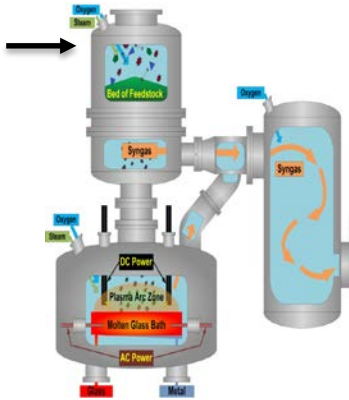
- Feedstock: Hazardous waste with high quantities of chlorine
- Products: Aqueous HCl and Syngas used as Boiler Fuel

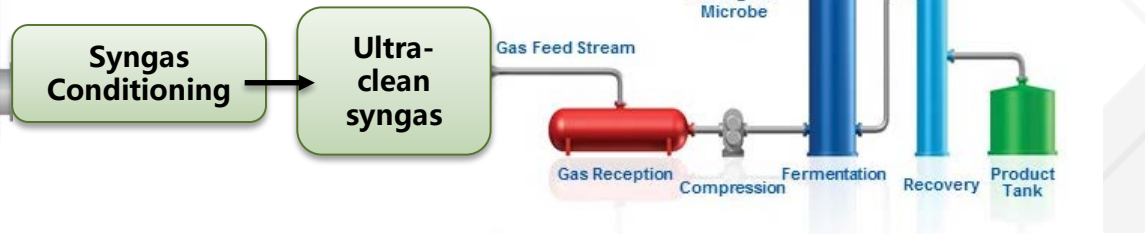
MOBILE PEM SYSTEM

AEMETIS INC., CALIFORNIA

- Feedstock: 450 ton/day orchard waste
- Product: 12 million gallons/year cellulosic ethanol
- Extremely low or negative carbon intensity under California rules







INENTEC SUMMARY

- Commercially proven proprietary technology
- Wide range of potential feedstocks
- Ultra-clean “chemical grade” syngas can be used to produce many products
- Modular and scalable
- Environmental beneficial, low impact

CONTACTS

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